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(54) Title: A NOVEL ANGIOGENESIS INHIBITOR

(57) Abstract: The present invention provides a novel angiogenesis inhibitor, LK68 whose amino acid sequence is identical with the human apolipoprotein (a) kringle domains IV36, IV37 and V38, a cDNA sequence encoding the LK68, a recombinant expression vector comprising the cDNA, a recombinant microorganism transformed with the recombinant expression vector and a novel use of the LK68 as an anticancer agent and a method for treating angiogenesis-mediated disease. LK68, LK6, LK7 and LK8 exhibit inhibitory activities on the cultured endothelial cell proliferation as well as on the endothelial cell migration. LK68 and its single kringles also inhibit the normal development of capillaries in the chick embryo chorioallantoic membrane (CAM). It was also showed that systemic administration of LK68 causes the inhibition of primary tumor growth, which is correlated with a suppression of tumor-induced angiogenesis. Accordingly, LK68 protein, its single kringles or their functional equivalents may be applied for the development of a potent anti-cancer agent, which is highly effective for angiogenesis-mediated diseases covering cancer, rheumatoid arthritis, psoriasis, ocular angiogenic disease, etc.

A NOVEL ANGIOGENESIS INHIBITOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a novel angiogenesis inhibitor, LK68 whose amino acid sequence is identical with the human apolipoprotein(a) kringle domains IV36, IV37 and V38, more specifically, to an amino acid sequence of the LK68, a cDNA sequence encoding the LK68, a recombinant expression vector comprising the cDNA, a recombinant microorganism transformed with the recombinant expression vector and a novel use of the LK68 as an anticancer agent and a method for treating the angiogenesis-mediated disease.

Description of the Prior Art

Angiogenesis is a biological process of generating new blood vessels into a tissue or organ. Under normal physiological conditions, humans or animals undergo angiogenesis only in very specific restricted situations. For example, angiogenesis is normally observed in wound healing, fetal and embryonal development and formation of the corpus luteum, endometrium and placenta. It has been reported that new vessel growth is tightly controlled by many angiogenic regulators (see: Folkman, J., Nature Med., 1: 27-31, 1995a), and the switch of the angiogenesis phenotype depends on the net balance between up-regulation of angiogenic stimulators and down-regulation of angiogenic suppressors.

An imbalance of the angiogenic process has been shown to contribute to pathological disorders such as diabetic retinopathy, rheumatoid arthritis and psoriasis (see: Folkman, J., Nature Med., 1: 27-31, 1995a).

Especially, both primary and metastatic tumors need to recruit angiogenic vessels for their growth (see: Folkman, J., New Engl. J. Med., 285:1182-1186, 1971; Folkman, J., J. Biol. Chem., 267:10931-10934, 1992). If this angiogenic activity could be repressed or eliminated, then the tumor, although present, would not grow. There are many reports suggesting that inhibiting tumor angiogenesis should provide a practical approach to long term control of the disease. Blocking positive regulators of angiogenesis or utilizing negative regulators to suppress angiogenesis results in a delay or regression of experimental tumors. If the angiogenic activity could be repressed or eliminated, then the tumor, although present, would not grow. Moreover, in the disease state, prevention of angiogenesis could avert the damage caused by the invasion of the new microvascular system effectively. Therefore, therapies directed at control of the angiogenic process could lead to the abrogation or mitigation of these diseases.

Therefore, what is needed is a novel angiogenesis inhibitor which can inhibit the unwanted growth of blood vessels, especially into tumors. An anticancer agent comprising the angiogenesis inhibitor should be able to overcome the activity of endogenous growth factors in premetastatic tumors and prevent the formation of the capillaries in the tumors thereby inhibiting the growth of the tumors. The anticancer agent should also be able to modulate the formation of capillaries in other angiogenic processes, such as wound healing and reproduction. Finally, the anticancer agent and method for inhibiting angiogenesis should preferably be non-toxic and produce few side-effects.

Until now, at least 10 endogenous angiogenic inhibitors have been identified in the art (see: O'Reilly, M. S. *et al.*, Cell, 88: 277-285, 1997). One such molecule is angiostatin, which consists of the plasminogen kringle I through IV(see: O'Reilly, M. S.

et al., Cell, 79:315-328, 1994). When applied systemically, angiostatin powerfully inhibits both primary tumor growth and metastasis without toxicity, and angiogenesis induced by bFGF as well (see: O'Reilly, M. S. *et al.*, Nature Med., 2:689-692, 1996). These anti-tumor effects were accompanied by a marked reduction of microvessel density within the tumor mass, indicating that suppression of angiogenesis was associated with the inhibition of tumor growth.

Kringles are protein structural domains composed of approximately 80 amino acids and three intramolecular disulfide bonds. Kringle structures are found in many proteins such as prothrombin (see: Walz, D. A. *et al.*, Proc. Natl. Acad. Sci., U.S.A., 74:1969-1973, 1977), plasminogen(see: Ponting, C. P., Blood Coagul. & Fibrinolysis, 3:605-614, 1992), urokinase(see: Pennica, D. *et al.*, Nature, 301:579-582 1983), hepatocyte growth factor(see: Lukker, N. A. *et al.*, Protein Eng., 7:895-903, 1994), and apolipoprotein("apo")(a)(see: McLean, J. W. *et al.*, Nature, 330:132-137, 1987). These domains appear to be independent folding units, but their functional role is not yet known. The previous reports represent that the kringle structure can act as inhibitors of endothelial cell migration and proliferation during angiogenesis. Specifically, prothrombin's kringle 2 and plasminogen's kringle 1-4, and 5 have been shown to be anti-angiogenic(see: Ji, W. R. *et al.*, FASEB J., 15:1731-1738, 1998a; Ji, W. R. *et al.*, Biochem. Biophys. Res. Commun., 247:414-419, 1998b; Cao, Y. *et al.*, J. Biol. Chem., 271:29461-29467, 1996; Cao, Y. *et al.*, J. Biol. Chem., 272:22924-22928, 1997; Barendsz-Janson, A. F., J. Vasc. Res., 35:109-114, 1998; Lee, T. H. *et al.*, J. Biol. Chem., 273:28805-28812, 1998).

Apolipoprotein(a), one of the proteins having kringle structures, is a candidate for a novel angiogenesis inhibitor. Apo(a) is covalently attached to

apoB-100, the main protein component of low density lipoprotein(LDL) to form lipoprotein(a)(see: Fless, G. M., J. Biol. Chem., 261: 8712-8718, 1986). Elevated plasma concentration of Lp(a) represents a major independent risk factor for artherosclerosis(see: Armstrong, V. W. *et al.*, Artherosclerosis, 62:249-257, 1986; Assmann, G., Am. J. Cardiol., 77:1179-1184, 1996; Bostom, A. G. *et al.*, JAMA, 276:544-548, 1996). Although several pathogenic activities have been reported, the physiological role of apo(a) has not yet been established(see: Lawn, R. M. *et al.*, J. Biol. Chem., 271:31367-31371, 1996; Scanu, A. M. and Fless, G. M., J. Clin. Invest., 85:1709-1715, 1990; Utermann, G., Science, 246:0904-910, 1989).

Apo(a) contains two types of kringle domains and an inactive protease-like domains: the first 37 kringle domains are ~75% identical to plasminogen kringle IV, and the last kringle domain is 90% identical to plasminogen kringle V. Interestingly, the kringle IV-like domain is present in 15-40 copies in different human alleles of the apo(a) gene. In this regard, it is feasible to develop an inhibitor of tumor angiogenesis and growth employing the Apo(a) kringle structures.

SUMMARY OF THE INVENTION

In accordance with the present invention, the inventors have cloned and expressed the human apo(a) kringles containing IV36, IV37 and V38 as a recombinant protein LK68, and discovered that: the LK68 protein and its single kringles, LK6, LK7 and LK8, have an ability to overcome the angiogenic activity of endogenous growth factors such as bFGF *in vitro*; and they may be used as active ingredients of anticancer agents.

The first object of the invention is, therefore, to provide a novel LK68 protein consisting of human apo(a)

kringle domains IV36, IV37 and V38, and cDNA encoding the LK68 protein.

The second object of the invention is to provide a novel recombinant vector containing the cDNA encoding human apo(a) kringle domains IV36, IV37 and V38.

The third object of the invention is to provide an anticancer agent which comprises the LK68 protein or its single kringles, LK6, LK7 and LK8, as an active ingredient.

The fourth object of the invention is to provide a method for treating angiogenesis-mediated disease by employing the LK68 protein.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and the other objects and features of the present invention will become apparent from the following description given in conjunction with the accompanying drawings, in which:

Figure 1 is a photograph of a SDS-polyacrylamide gel electrophoresis for analysis of recombinant LK68 protein expressed in *E. coli*.

Figure 2 is a photograph showing the inhibition of angiogenesis by LK68 on the chick chorioallantoic membrane (CAM).

Figure 3(A) is a graph showing inhibition of vessel growth in the CAM as a function of LK68.

Figure 3(B) is a graph showing inhibition of vessel growth in the CAM as a function of single kringles, LK6, LK7, LK8, and a control.

Figure 4(A) is a graph showing inhibition of BCE cell proliferation by recombinant LK68 and angiostatin.

Figure 4(B) is a graph showing inhibition of BCE cell proliferation by recombinant LK6, LK7 and LK8.

Figure 4(C) is a graph showing inhibition of HUVEC cell proliferation by recombinant LK68 and LK8.

Figure 5(A) is a graph showing BrdU labeling index of LLC cells in the presence of recombinant LK68 and LK8.

Figure 5(B) is a graph showing BrdU labelling index of Y1 cells in the presence of recombinant LK68 and LK8.

Figure 5(C) is a graph showing BrdU labelling index of TIB74 cells in the presence of recombinant LK68 and LK8.

Figure 5(D) is a graph showing BrdU labelling index of CHO cells in the presence of recombinant LK68 and LK8.

Figure 5(E) is a graph showing BrdU labelling index of MSF cells in the presence of recombinant LK68 and LK8.

Figure 5(F) is a graph showing BrdU labelling index of NIH3T3 cells in the presence of recombinant LK68 and LK8.

Figure 6(A) is a graph showing inhibition of HUVEC cell migration by recombinant LK68, LK8 and PK5.

Figure 6(B) is a graph showing inhibition of HUVEC cell migration by recombinant LK68, LK6, LK7 and LK8.

Figure 7 is a graph showing inhibition of BCE cell migration by angiostatin, recombinant LK68, LK6, LK7, and LK8 and combination of single kringles.

Figure 8 shows the effect of administration of LK68 to mice having implanted Lewis lung carcinoma cells on total volume as a function of time.

Figures 9(A) to 9(C) are photographs showing histological analyses of Lewis lung carcinoma cells by hematoxylin and eosin (H/E) staining.

Figure 10 shows the effect of administration of LK68 to nude mice having implanted human lung carcinoma A549 cells on total volume as a function of time.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a novel protein LK68, which can be cloned and expressed as recombinant protein from the human apolipoprotein("apo")(a) kringles. The LK68 protein consists of amino acid sequences of human

apolipoprotein(a) kringle domains IV36(amino acid 8 to 80), IV37(amino acid 122 to 194) and V38(amino acid 226 to 300) in a serial manner(see: SEQ ID NO: 2). The first two kringle domains of LK68 (i.e., IV36 and IV37) are homologous to human plasminogen kringle IV, and the third kringle domain V38 is homologous to human plasminogen kringle V. The present invention also provides a cDNA encoding the LK68 protein (see: SEQ ID NO: 1) and recombinant vectors which comprises the said cDNA and expression vectors such as pET vector series.

In describing the kringle domains of the invention, human apolipoprotein(a) kringles IV36, IV37 and V38 are abbreviated as KIV36, KIV37 and KV38, respectively; LK68 is employed to mean the recombinant protein which comprises the said three kringle domains; and, LK6, LK7 and LK8 are employed to mean the recombinant proteins of KIV36, KIV37 and KV38, respectively.

Because apolipoprotein(a) contains plasminogen-type IV and V kringle domains, it was assumed that apolipoprotein(a) could possibly have an anti-angiogenic activity. There is an experimental evidence suggesting apolipoprotein(a) may contain biological activity as an inhibitor of tumor angiogenesis and growth(see: Trieu, V. N. and Uckun, F. M., Biochem. Biophys. Res. Commun., 257:714, 1999). It has been reported that LL/2(Lewis Lung Carcinoma) tumor growth is delayed in apo(a) transgenic mice and the microvessel density of LL/2 tumors from apo(a) transgenic mice is lower than that from wild-type mice as control.

Under the circumstance, the present inventors assumed that LK68 protein, its single kringles or their functional equivalents may have an anti-angiogenic activity. To verify said anti-angiogenic activity, it was investigated whether recombinant LK68 and its single kringles (i.e., LK6, LK7 and LK8) are potent anti-angiogenic factors *in vitro* and *in vivo* as well. As a result, LK68, LK6, LK7 and LK8 exhibit inhibitory

activities on the cultured endothelial cell proliferation as well as on the endothelial cell migration. LK68 and its single kringles also inhibit the normal development of capillaries in the chick embryo chorioallantoic membrane (CAM). It was also shown that systemic administration of LK68 inhibited the primary tumor growth, which is correlated with a suppression of tumor-induced angiogenesis. Since each of the single kringle proteins, LK6, LK7 and LK8 showed anti-angiogenic activity, it is expected that they also inhibit the primary tumor growth or metastasis.

Accordingly, LK68 protein, its single kringles or their functional equivalents may be applied for the development of a potent anti-cancer agent, which is highly effective for angiogenesis-mediated diseases covering reumatoid arthritis, psoriasis, or ocular angiogenic diseases, etc.

Also, LK68 protein, its single kringles or their functional equivalents may be used in combination with other compositions and procedures for the treatment of diseases. For example, tumor may be treated conventionally with surgery, radiation or chemotherapy combined with LK68, its single kringles, or their functional equivalent, and then LK68, its single kringles, or their functional equivalent may be subsequently administered to the patient to extend the dormancy of micrometastases and to stabilize and inhibit the growth of any residual primary tumor.

The present invention is further illustrated in the following examples, which should not be taken to limit the scope of the invention.

Example 1: Cloning and Expression of Recombinant LK68

In order to verify the anti-angiogenic activity of human apo(a) kringle, the inventors cloned and expressed

the last three kringles containing IV36, IV37 and V38 as a recombinant protein LK68. A DNA fragment of apo(a) spanning nucleotides 12,052 to 12,975(see: McLean J. W. et al., Nature, 330:132, 1987) was PCR-amplified from human liver cDNA and the resulting 924-bp *NdeI-BamHI* fragment was ligated into *E.coli* expression vector pET11a(Novagen, USA). The oligonucleotide primers A(SEQ ID NO: 9)and F(SEQ ID NO: 14)(see: Table 1) were used for PCR amplification under the standard PCR protocol. This clone was named "pET11a/LK68", which encodes 308 amino acids including human apo(a) kringle domains, IV36, IV37 and V38(see: SEQ NO ID: 2). The first two kringle domains of this clone, IV36 and IV37, are homologous to human plasminogen kringle IV, and the third kringle domain V38 is homologous to human plasminogen kringle V.

The nucleotide sequences of this clone were confirmed in both directions. When the nucleotide sequence of this clone was compared to the same region of the human apo(a)(see: McLean J. W. et al., Nature, 330:132, 1987), the nucleotide sequences are identical with the exception of a single base change at nucleotide 554. Our clone contains a cytosine at this position as compared to a thymidine in the sequence reported by McLean *et al.*(see: McLean J. W. et al., Nature, 330:132, 1987), causing an amino acid change to Thr from Met. This substitution has also been reported by other groups(see: Van der-Hoek, Y. Y. *et al.*, Hum. Mol. Genet., 2:361-366, 1993; LoGrasso, P. V. *et al.*, J. Biol. Chem., 269:21820-21827, 1994) and appears to be the predominant allele for apo(a).

E. coli BL21(DE3) was transformed with an expression plasmid pET11a/LK68 and recombinant LK68 protein was expressed under the following conditions. One liter of Luria-Bertani broth containing ampicillin was inoculated with 10ml of an overnight culture of *E. coli* BL21(DE3) harboring the pET11a/LK68 plasmid and incubated with shaking at 37℃. When the OD_{600} of the

culture reached 0.4-0.6, isopropylthio-β-D-galactoside(IPTG) was added at a final concentration of 1mM. Cells were grown an additional 4h after induction. Cells were harvested by centrifugation at 8000xg for 30min at 4℃. These cell pellets were sonicated and the over-expressed proteins were analyzed by SDS-PAGE(see: Figure 1). In Figure 1, Mr represents a molecular weight marker(Boehringer Mannheim, Germany); lane 1, the expression of recombinant LK68 protein without IPTG induction; and, lane 2, the expression of recombinant LK68 protein with IPTG induction, respectively. Recombinant LK68 protein having a molecular weight of 37kDa was well expressed in *E. coli*, accumulating to about 20-30% of the total protein, as evidenced by image analysis of the scanned gel. The transformant thus prepared was designated as '*Escherichia coli* BL21/LK6-8', and deposited with the Korean Collection for Type Cultures, #52 Oun-dong, Yusong-ku, Taejon 305-333, Republic of Korea, an international depository authority as accession No. KCTC0633BP on Jun. 9, 1999.

Each of single kringle domains, IV36, IV37 and V38, was cloned separately into an expression vector pET15b as described above. The oligonucleotide primers used for cloning are listed in Table 1: that is, A(SEQ ID NO: 9) and D(SEQ ID NO: 12) for KIV36 cloning; B(SEQ ID NO: 10) and E(SEQ ID NO: 13) for KIV37 cloning; and, C(SEQ ID NO: 11) and F(SEQ ID NO: 14) for KV38 cloning, respectively. These three couples of oiligonucleotide primers were used for PCR amplification under the standard PCR protocol and the resulting clones were named "pET15b/LK6", "pET15b/LK7" and "pET15b/LK8", each of which includes the single human apo(a) kringle domains of IV36, IV37 and V38, respectively. *E. coli* BL21(DE3) competent cells were transformed with each of the expression plasmid, pET15b/LK6, pET15b/LK7 and pET15b/LK8. The transformant with plasmid pET15b/LK6

thus prepared was designated as '*Escherichia coli* BL21(DE3)/LK6', and deposited with the Korean Collection for Type Cultures, #52 Oun-dong, Yusong-ku, Taejon 305-333, Republic of Korea, an international depository authority as accession No. KCTC0655BP on Sept. 3, 1999. The transformant with plasmid pET15b/LK7 thus prepared was designated as '*Escherichia coli* BL21(DE3)/LK7', and deposited with the Korean Collection for Type Cultures on the same address as above, an international depository authority as accession No. KCTC0656BP on Sept. 3, 1999. The transformant with plasmid pET15b/LK8 thus prepared was designated as '*Escherichia coli* BL21/LK8', and deposited with the Korean Collection for Type Cultures on the same address as above, an international depository authority as accession No. KCTC0634BP on Jun. 9, 1999.

Recombinant LK6, LK7 and LK8 proteins were expressed under the same conditions as fusion proteins containing N-terminal His-tag. Each of the over-expressed recombinant LK6, LK7 and LK8 protein was purified using pET His-tag system under the manufacturer's recommended condition.

Table 1. Oligonucleotide primers used for PCR cloning

Nucleotide Sequences*	Description	Location**	SEQ ID NO.
A. TCCATATGAAAAGCCCTGTGGTCCAGGAT	K36-5'	12052-12072	9
B. CAGTCCATATGGTCCGCCAGTGCTACCATGGCA	K37-5'	12406-12427	10
C. GGAATTCCATATGGAACAGGACTGCATGTTT	K38-5'	12718-12735	11
D. CGGGATCCTTAACCTGATTCTGTTTC	K36-3'	12310-12323	12
E. CGGGATCCTTAGACCACAGTCCCTTC	K37-3'	12658-12671	13
F. CGGGATCCTTAAGAGGATGCACA	K38-3'	12964-12975	14

* Restriction sites, *Nde*I and *Bam*HI are added for the cloning

conveniences(underlined).

** See: McLean *et al.*, Nature, 330:132, 1987, for nucleotide sequence(accession number is X06290).

Example 2: Purification of the Recombinant LK68

In order to produce the recombinant LK68, high cell-density fermentation was performed in a 5L Bioflow III bioreactor(New Brunswick Scientifics, Edison, USA) in the following medium: 4%(w/v) yeast extract, 4%(w/v) glycerol, 1%(w/v) dibasic sodium phosphate, 0.2%(w/v) monobasic potassium phosphate and 50μg/ml ampicillin. When the cells reached an absorbance of 100 at 600 nm, protein expression was induced with 1mM IPTG and then DO-stat fed-batch was carried out for 9h with feed media(29%(w/v) yeast extract, 39%(w/v) glycerol and 0.5%(w/v) magnesium sulfate. Cells were harvested by centrifugation at 8000xg for 30 min. Each fermentation process yielded about 80g of cell/L(wet weight).

To assess if LK68 was expressed in the soluble fraction or the insoluble cellular fraction of *E.coli* cells, the inventors analyzed the LK68 expression in these fractions. This analysis showed that LK68 was located in the insoluble cellular fraction. Thus, it was necessary to denature, refold and reoxidize the disulfied bonds of LK68. By using the deoxycholate and other detergents, the insoluble LK68 protein was purified as inclusion bodies to the extent of >95% purity. Then, the inclusion bodies were solublized with 7M urea and folded into native conformation using a rapid dilution and an equilibrium dialysis scheme. In the folding buffer, purified inclusion bodies were easily refolded without detectable protein aggregation. After the dialysis, the protein was purified by lysine-Sepharose 4B affinity chromatography. The protein bound to lysine-Sepharose was specifically eluted by ε-ACA(ε-amino-n-caproic acid). This suggested that the lysine-

binding site located in the KIV37 kringle of the refolded protein was fully functional. Affinity elution of LK68 with 0.1M ε-ACA yielded about 3mg of protein/g of cells(wet weight). Chromatography with polymyxin-B beads(Sigma Chemical Co., USA) was subsequently performed to eliminate any endotoxin, and residual endotoxin activity was determined with the *Limulus* amebocyte lysate assay kit(Biowhittaker Inc., USA). The purified protein was analyzed by SDS-PAGE and was stored at -20℃ until needed. The calculated pI value of LK68 protein is 6.13. The N-terminal amino acid sequence of the purified LK68 was confirmed by amino acid sequencing.

Example 3: Chick Chorioallantoic Membrane Assay

In order to determine whether LK68 is anti-angiogenic *in vivo*, the inventors tested its ability to inhibit the development of capillaries in the chorioallantoic membrane("CAM")(see: Lee, T. H. *et al.*, J. Biol. Chem., 273:28805-28812, 1998). Fertilized three-day-old eggs were incubated at 37℃, and a window was made after the extraction of ovalbumin. After two days of incubation, a Thermanox coverslip(Nunc Inc., USA) containing recombinant LK68 protein was applied to the CAM of individual embryos. After 48h, 20% fat emulsion was injected into the chorioallantois of the embryos, and the vessel formation around the Thermanox was examined(see: Figure 2). In Figure 2, the left photograph shows the normal development of capillaries in the CAM; and, the right shows the inhibition of angiogenesis by LK68 on CAM, respectively.

When LK68 at the dose range of 3 - 5μg was applied on the CAM, more than 60 % among the 100 eggs tested showed avascular zone around the sample applied, indicating that the growth of capillaries was inhibited. With the recombinant proteins of each kringle domain, e.g. LK6, LK7 or LK8, 60 - 70% of the eggs tested showed

inhibitory effects at the dose range of 1μg/CAM(see: Figures 3(A) and 3(B)). This *in vivo* study showed that apo(a) kringle domains have anti-angiogenic activity and LK68 as well as single kringle proteins is a potent inhibitor of angiogenesis. There was no evidence of toxicity in any of the chick embryos tested.

Example 4: Inhibition of Endothelial Cell Proliferation

Recombinant LK68, LK6, LK7 and LK8 proteins were assayed for their inhibitory activity on proliferation of bovine capillary endothelial (BCE) cells stimulated by bFGF under the following conditions. BCE cells were grown in DMEM containing 10% bovine calf serum (BCS) and 3 ng/ml bFGF(Upstate Biotechnology, USA). Approximately 3,000 cells were added to each well of 96-well tissue culture plate and incubated at 37 °C in 5% CO_2 atmosphere. After incubation for 18 h, the medium was replaced with DMEM containing 0.5% BCS, and the test samples were added to each well. After 30 min incubation, bFGF was added to a final concentration of 1ng/ml. The cell count was determined by [^{3}H]thymidine incorporation method. The experiments were performed in triplicate.

As can be seen in Figure 4, it was determined that LK68, LK6, LK7 and LK8 specifically inhibited BCE cell proliferation in a dose-dependent manner. When the angiostatin was applied as a positive control, all the Apo(a) kringle proteins tested appeared to be more effective under the conditions used in this experiment. The concentration of half-maximal inhibition (ED_{50}) for LK68 is determined about 200 - 250nM, about 140 - 170nM for LK6, about 10 - 20nM for LK7, and about 10 - 20nM for LK8 (see: Figures 4(A) and 4(B)).

Recombinant LK68 and LK8 proteins were assayed for their inhibitory activity on proliferation of human umbilical vein endothelial (HUVEC) cells stimulated by bFGF under the following conditions. HUVECs(American

Type Culture Collection, USA) were grown in F12K medium containing 10% heat-inactivated fetal bovine serum("FBS")(Hyclone, USA), 30μg/ml endothelial cell growth supplement(ECGS)(Sigma Chemical Co., USA), and 100μg/ml heparin(Sigma Chemical Co., USA). The cells were plated at a density of 2000/well in 96-well tissue culture plate. The cells were incubated at 37℃, 5% CO_2, for 18hr, washed once with serum-free medium, and F12 medium containing 0.5% FBS was added. The cells were treated with various concentrations of samples and incubated for 30min. Then, ECGS, heparin and bFGF(Upstate Biotechnology, USA) were added into the cells with the final concentrations of 30μg/ml, 100μg/ml and 5ng/ml, respectively. After 48hr of incubation, cell counts were determined with the Cell Proliferation ELISA using 5-bromo-2'- deoxyuridine (BrdU)(Boehringer Mannheim, USA). The experiments were performed in triplicate.

As can be seen in Figure 4(C), it was determined that LK68 as well as LK8 specifically inhibited HUVEC cell proliferation in a dose-dependent manner.

In the presence of LK68 or single kringle proteins such as LK6, LK7 and LK8, the morphology of BCE or HUVEC cells appeared similar to those of untreated cells. In addition, cell proliferation can be rescued with bFGF stimulation after removal of LK68. These results indicate that LK68 as well as single kringle proteins are not cytotoxic to capillary endothelial cells. Furthermore, the inhibitory activity would appear to be specific for endothelial cells, e.g., BCE and HUVEC cells. Additionally, LK68 as well as LK8 failed to show inhibition of proliferation of non-endothelial cell types, such as CHO cells, mouse skin fibroblast NIH3T3 cells, mouse Lewis lung carcinoma cells, mouse adrenal tumor Y1 cells and mouse embryonic liver/SV40 transformed cell line TIB74(see: Figures 5(A) to 5(F)). Figures 5(A) to 5(C) represent the sensitivity of

various tumor cells such as LLC, Y1, and TIB 74, and Figures 5(D) to 5(F) represent the sensitivity of various normal cell lines such as CHO, MSF, and NIH3T3, respectively.

Example 5: Inhibition of Endothelial Cell Migration

Cell migration assay was performed in Transwells with 8-mm pores (Costar, USA). Briefly, the wells were coated with fibronectin(25μg/ml)(Sigma Chemical Co., USA) overnight and HUVECs were plated at a density of 2000/well in 100 μl Dulbecco's modified Eagle's medium containing 0.4% fetal calf serum(FCS) in the upper chamber. 500μl of DMEM containing 0.4% FCS was added to the lower chamber and incubated at 37℃ for 1 hr. The test samples of 1μM concentration were added to the upper chamber and 25 ng/ml of bFGF was added to the lower chamber. After 5 hr incubation, cells that crossed the fibronectin-plated membrane were quantified after wiping off the cells in the upper chamber with a cotton swab. The cells across the membrane were stained with Diff-Quik stain set according to the manufacturer's instruction (Dade Behring Inc., USA) and were counted at 100x magnification. The experiments were performed in duplicate.

Basic FGF(25ng/ml) was used to stimulate the migration of HUVEC cells. With the dose of 1μM, LK68 as well as single kringle proteins such as LK6, LK7 and LK8 completely inhibited the bFGF-induced HUVEC cell migration to the level of uninduced control(see: Figures 6(A) and 6(B)). In Figure 6, (-)CON represent uninduced control, and (+)CON represent bFGF-induced positive control.

Migration assay using BCE cells was performed as described above. Two different concentrations of LK68 or single kringle proteins applied and all the Apo(a) kringle proteins tested showed inhibitory effects on BCE

cell migration. In addition, LK68 and its single kringle proteins were more effective on the inhibition of BCE cell migration than angiostatin(AS)(see: Figure 7).

Example 6: Suppression of Primary Tumor Growth

Example 6-1: Lewis Lung Carcinoma

Male 6 to 8-week-old C57BL6/J mice were implanted with Lewis lung carcinomas. The subcutaneous dorsa of mice in the proximal midline were injected with 1 x 10^6 cells in 0.1ml of saline. When the tumors reached about 5mm in diameter, tumor-bearing mice received LK68(100 mg/kg body weight) as a suspension in PBS injected subcutaneously at a site distant from the tumor. The control group of mice had only a sham procedure and was treated with PBS only. Tumor size was measured every day during the treatment; and, volumes were determined using the formula width^2 x length x 0.52 and the ratio of treated to control tumor volume(T/C) was determined for the last time point. Treatments were continued for 8 days, at which point all mice were sacrificed and the tumors were removed(see: Figure 8). As can be seen in Figure 8, it was clearly determined that the growth of LLC primary tumors was potently suppressed by systemic LK68 therapy; LK68 at a dose of 100mg/kg caused significant regression of tumor burden only with 7 day treatment.

Histological analyses were also carried out to compare tumors from treated and control mice in terms of vessel density and hemorrhage formation, and morphological appearance(see: Figures 9(A) to 9(C)). In Figures 9(A) to 9(C), 9(A) shows PBS-treated control, 9(B) LLC tumors of 10mg/kg body weight LK68-treated, and 9(C) LLC tumor of 100mg/kg body weight LK68-treated, respectively. Obvious histological differences were observed in LK68-treated tumors by hemotoxylin and

eosin(H/E) staining: that is tumor cells were not intact and morphologically not viable; and, zonal necrosis was examined around the tumors. Also, vessel density within LK68-treated tumors was reduced. There was no evidence of inflammation or bleeding in any of the mice treated with the recombinant LK68.

Example 6-2: Human Lung Carcinoma

Four-week-old outbred female *nu/nu* nude mice used in this experiment were housed in a sterile environment. Cages, bedding, food and water were all autoclaved. The mice were maintained on a 12-hr light/ 12-hr dark cycle. Human lung cancer cells (A549 purchased from Korean Cell Line Bank) were maintained in RPMI 1640 medium, supplemented with 10% heat-inactivated FBS and antibiotics. Approximately 2 x 10^7 cells of A549 human lung carcinoma were subcutaneously injected into nude mice into the proximal midline of the dorsa. When tumors were palpable at day 7 after tumor implantation, the mice were treated with LK68 at the dose of 100mg/kg body weight. The control group was treated with PBS only. The treatment was continued for 17 days. The tumor size was measured every other day.

The tumor growth was regressed by the LK68 treatment: that is, LK68-treated A549 tumors were approximately 57.5% smaller than tumors in control animals(see: Figure 10). There was no evidence of any toxicity in any of the treated mice. Continued therapy maintained the tumors in a state of dormancy for as long as it was administered. These data strongly suggest that the anti-angiogenic effect of LK68 can be used to target a wide variety of primary malignancies.

As clearly illustrated and demonstrated as above, the present invention provides a novel angiogenesis inhibitor, LK68 whose amino acid sequence is identical

with the human apo(a) kringle domains IV36, IV37 and V38, a DNA sequence encoding the LK68, a recombinant expression vector comprising the DNA, a recombinant microorganism transformed with the recombinant expression vector, use of the LK68 as an anticancer agent, and a method for treating angiogenesis-mediated disease.

BUDAPEST TREATY ON THE INTERNATIONAL RECOGNITION OF THE DEPOSIT OF MICROORGANISMS FOR THE PURPOSE OF PATENT PROCEDURE

INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

issued pursuant to Rule 7.1

TO: Mogam Biotechnology Research Institute
#341, Pojung-ri, Koosung-myun, Yongin-si, Kyonggi-do 449-910,
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM	
Identification reference given by the DEPOSITOR: ***Escherichia coli*** **BL21(DE3)/LK6**	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: **KCTC 0355BP**

II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION

The microorganism identified under I above was accompanied by:
[x] a scientific description
[ ] a proposed taxonomic designation
(Mark with a cross where applicable)

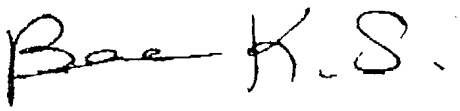
III. RECEIPT AND ACCEPTANCE

This International Depositary Authority accepts the microorganism identified under I above, which was received by it on **Sep 03 1999.**

IV. RECEIPT OF REQUEST FOR CONVERSION

The microorganism identified under I above was received by this International Depositary Authority on and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on

V. INTERNATIONAL DEPOSITARY AUTHORITY

Name: **Korean Collection for Type Cultures** Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB) #52, Oun-dong, Yusong-ku, Taejon 306-333, Republic of Korea	Signature(s) of person(s) having the power to represent the International Depositary Authority of authorized official(s):  BAE, Kyung Sook, Director Date: **Sep 08 1999**

BUDAPEST TREATY ON THE INTERNATIONAL RECOGNITION OF THE DEPOSIT OF MICROORGANISMS FOR THE PURPOSE OF PATENT PROCEDURE

INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

issued pursuant to Rule 7.1

TO: Mogam Biotechnology Research Institute
#341, Pojung-ri, Koosung-myun, Yongin-si, Kyonggi-do 449-910,
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM	
Identification reference given by the DEPOSITOR: ***Escherichia coli*** **BL21(DE3)/LK7**	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: **KCTC 0858BP**

II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION

The microorganism identified under I above was accompanied by:
[x] a scientific description
[ ] a proposed taxonomic designation
(Mark with a cross where applicable)

III. RECEIPT AND ACCEPTANCE

This International Depositary Authority accepts the microorganism identified under I above, which was received by it on **Sep 03 1999.**

IV. RECEIPT OF REQUEST FOR CONVERSION

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V. INTERNATIONAL DEPOSITARY AUTHORITY	
Name: **Korean Collection for Type Cultures** Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB) #52, Oun-dong, Yusong-ku, Taejon 305-333, Republic of Korea	Signature(s) of person(s) having the power to represent the International Depositary Authority of authorized official(s): Bae K.S. BAE, Kyung Sook, Director Date: **Sep 08 1999**

BUDAPEST TREATY ON THE INTERNATIONAL RECOGNITION OF THE DEPOSIT OF MICROORGANISMS FOR THE PURPOSE OF PATENT PROCEDURE

INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

issued pursuant to Rule 7.1

TO: Mogam Biotech. Research Institute
#341, Pojung-ri, Koosung-myun, Yongin-si, Kyonggi-do 449-910,
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM	
Identification reference given by the DEPOSITOR: ***Escherichia coli* BL21/LK8**	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: **KCTC 0634BP**

II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION

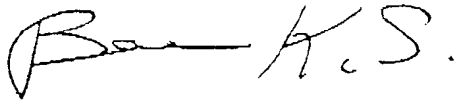
The microorganism identified under I above was accompanied by:
{ x } a scientific description
[ ] a proposed taxonomic designation
(Mark with a cross where applicable)

III. RECEIPT AND ACCEPTANCE

This International Depositary Authority accepts the microorganism identified under I above, which was received by it on **Jun 09 1999.**

IV. RECEIPT OF REQUEST FOR CONVERSION

The microorganism identified under I above was received by this International Depositary Authority on and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on

V. INTERNATIONAL DEPOSITARY AUTHORITY	
Name: **Korean Collection for Type Cultures** Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB) #52, Oun-dong, Yusong-ku, Taejon 305-333, Republic of Korea	Signature(s) of person(s) having the power to represent the International Depositary Authority of authorized official(s):  BAE, Kyung Sook, Director Date: **Jun 16 1999**

BUDAPEST TREATY ON THE INTERNATIONAL RECOGNITION OF THE DEPOSIT OF MICROORGANISMS FOR THE PURPOSE OF PATENT PROCEDURE

INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

issued pursuant to Rule 7.1

TO: Mogam Biotech. Research Institute
#341, Pojung-ri, Koosung-myun, Yongin-si, Kyonggi-do 449-910,
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM	
Identification reference given by the DEPOSITOR: *Escherichia coli* **BL21/LK6-8**	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: **KCTC 0633BP**

II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION

The microorganism identified under I above was accompanied by:
[x] a scientific description
[ ] a proposed taxonomic designation
(Mark with a cross where applicable)

III. RECEIPT AND ACCEPTANCE

This International Depositary Authority accepts the microorganism identified under I above, which was received by it on **Jun 09 1999.**

IV. RECEIPT OF REQUEST FOR CONVERSION

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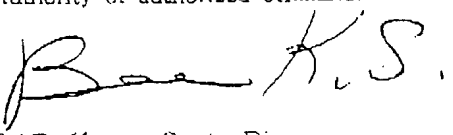
V. INTERNATIONAL DEPOSITARY AUTHORITY	
Name: **Korean Collection for Type Cultures** Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB) #52, Oun-dong, Yusong-ku, Taejon 305-333, Republic of Korea	Signature(s) of person(s) having the power to represent the International Depositary Authority of authorized official(s):  BAE, Kyung Sook, Director Date: **Jun 16 1999**

WHAT IS CLAIMED IS:

1. LK6 protein (SEQ ID NO: 4) consisting of amino acid sequences of human apolipoprotein(a) kringle domains IV36.

2. LK7 protein (SEQ ID NO: 6) consisting of amino acid sequences of human apolipoprotein(a) kringle domains IV37.

3. LK8 protein (SEQ ID NO: 8) consisting of amino acid sequences of human apolipoprotein(a) kringle domains V38.

4. LK68 protein (SEQ ID NO: 2) consisting of amino acid sequences of human apolipoprotein(a) kringle domains IV36, IV37 and V38 in a serial manner

5. A cDNA sequence(SEQ ID NO: 3) which codes for the LK6 protein of claim 1.

6. A cDNA sequence(SEQ ID NO: 5) which codes for the LK7 protein of claim 2.

7. A cDNA sequence(SEQ ID NO: 7) which codes for the LK8 protein of claim 3.

8. A cDNA sequence(SEQ ID NO: 1) which codes for the LK68 protein of claim 4.

9. A recombinant expression vector pET15b/LK6 comprising the cDNA of claim 5 which expresses the LK6 protein of claim 1.

10. A recombinant expression vector pET15b/LK7 comprising the cDNA of claim 6 which expresses the LK7 protein of claim 2.

11. A recombinant expression vector pET15b/LK8 comprising the cDNA of claim 7 which expresses the LK8 protein of claim 3.

12. A recombinant expression vector pET11a/LK68 comprising the cDNA of claim 8 which expresses the LK68 protein of claim 4.

13. *Escherichia coli* BL21(DE3)/LK6(KCTC0655BP) transformed with the recombinant expression vector pET15b/LK6 of claim 9.

14. *Escherichia coli* BL21(DE3)/LK7(KCTC0656BP) transformed with the recombinant expression vector pET15b/LK7 of claim 10.

15. *Escherichia coli* BL21/LK8(KCTC0634BP) transformed with the recombinant expression vector pET15b/LK8 of claim 11.

16. *Escherichia coli* BL21/LK6-8(KCTC0633BP) transformed with the recombinant expression vector pET11a/LK68 of claim 12.

17. An anticancer agent which comprises an active ingredient of LK68 protein, its single kringles, or their functional equivalents and pharmaceutically acceptable carrier.

18. A method for treating angiogenesis-mediated disease which comprises administering therapeutically effective amount of LK 68 protein, its single kringles, or their functional equivalents to a human or animal.

19. The method for treating angiogenesis-mediated disease of claim 18, wherein the angiogenesis-mediated

disease is cancer, rheumatoid arthritis, psoriasis, or ocular angiogenic disease.

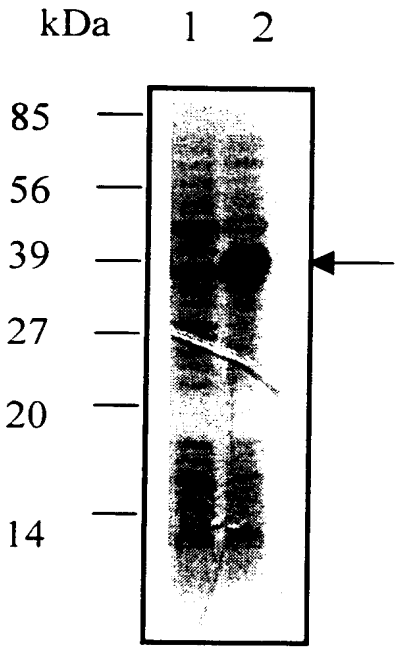


FIG. 1

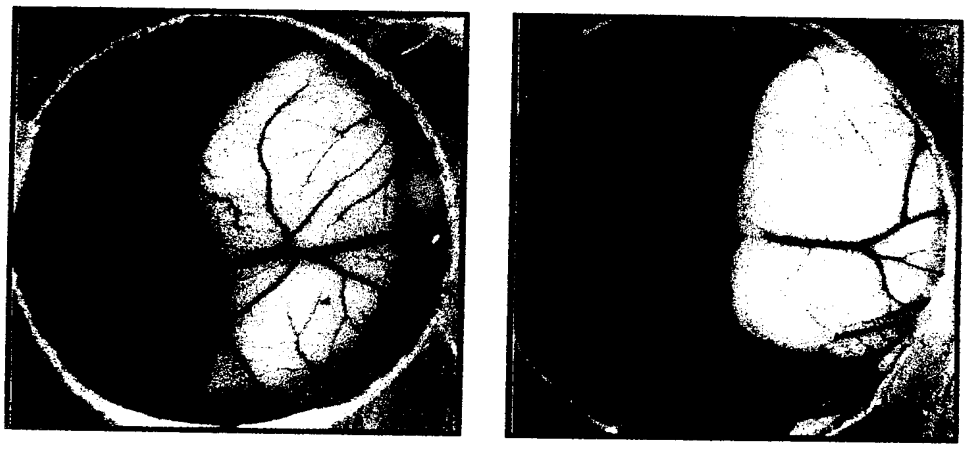


FIG. 2

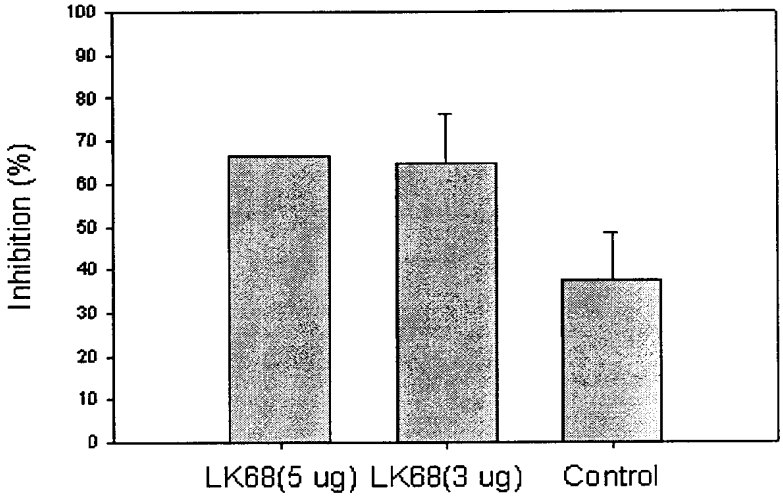

Inhibition (%)
100
90
80
70
60
50
40
30
20
10
0
LK68(5 ug)
LK68(3 ug)
Control

FIG. 3(A)

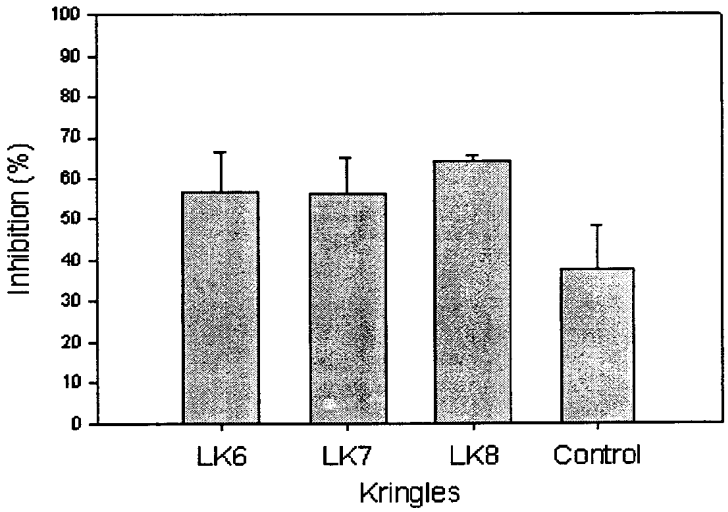

Inhibition (%)
100
90
80
70
60
50
40
30
20
10
0
LK6
LK7
LK8
Control
Kringles

FIG. 3(B)

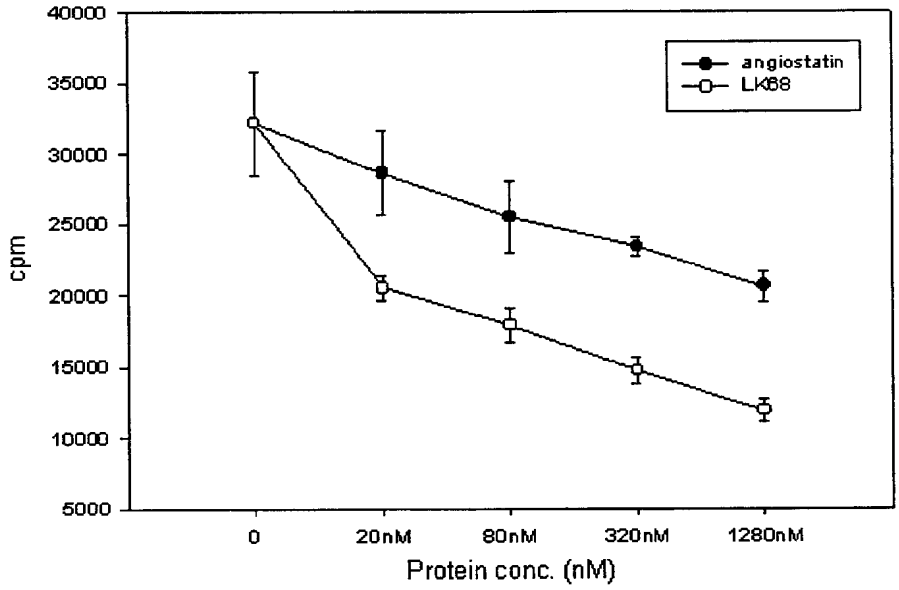

40000
35000
30000
25000
20000
15000
10000
5000
cpm
angiostatin
LK68
0
20nM
80nM
320nM
1280nM
Protein conc. (nM)

FIG. 4(A)

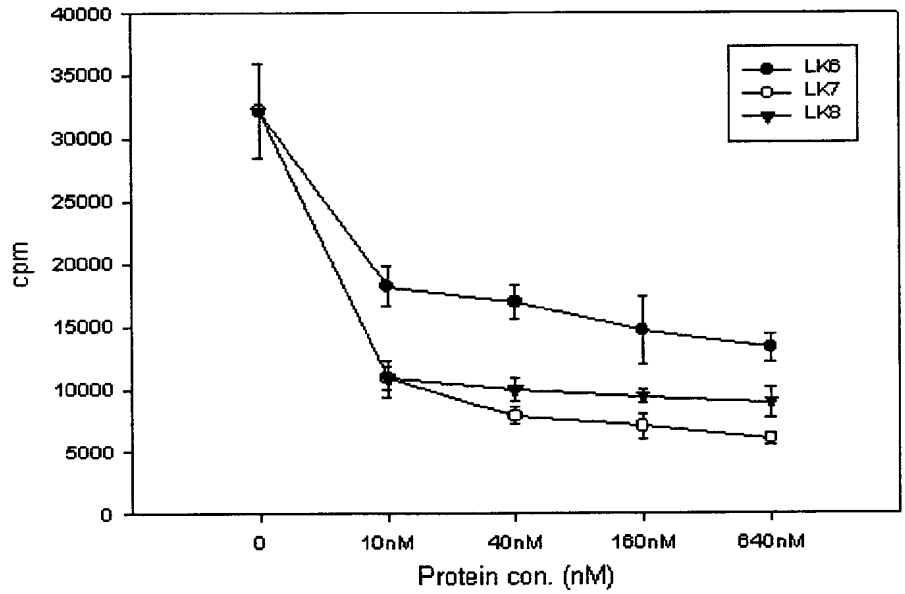

40000
35000
30000
25000
20000
15000
10000
5000
0
cpm
LK6
LK7
LK8
0
10nM
40nM
160nM
640nM
Protein con. (nM)

FIG. 4(B)

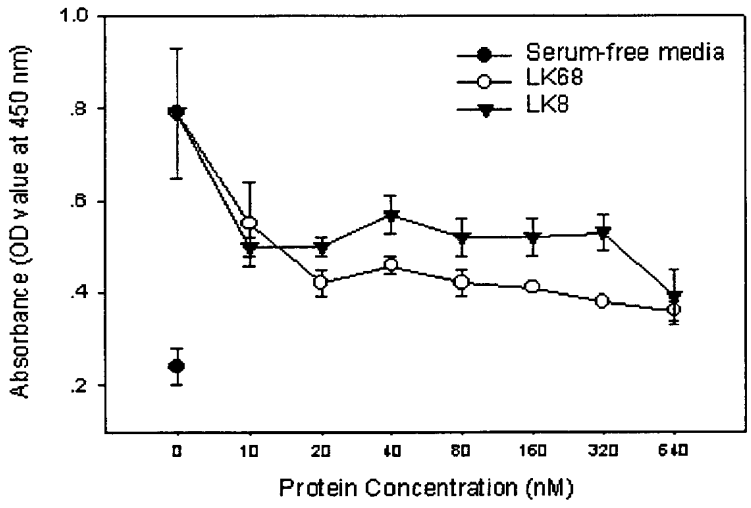

1.0
.8
.6
.4
.2
Absorbance (OD value at 450 nm)
Serum-free media
LK68
LK8
0
10
20
40
80
160
320
640
Protein Concentration (nM)

FIG. 4(C)

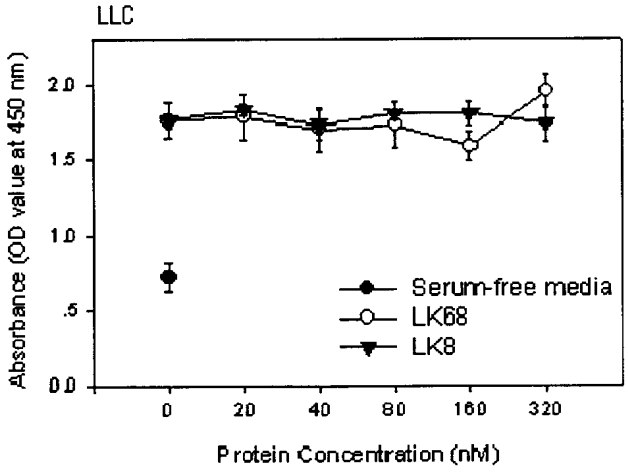


FIG. 5(A)

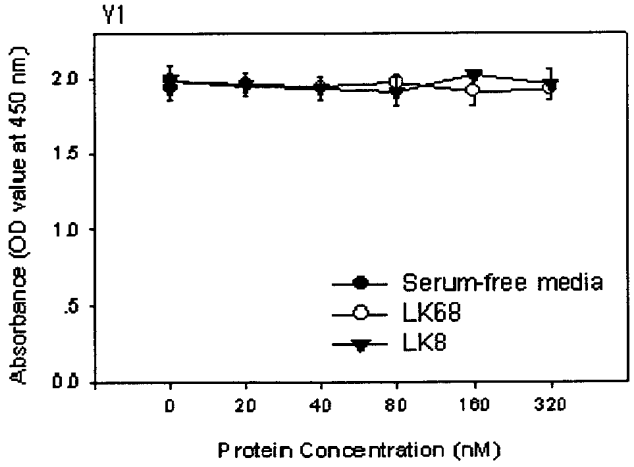


FIG. 5(B)

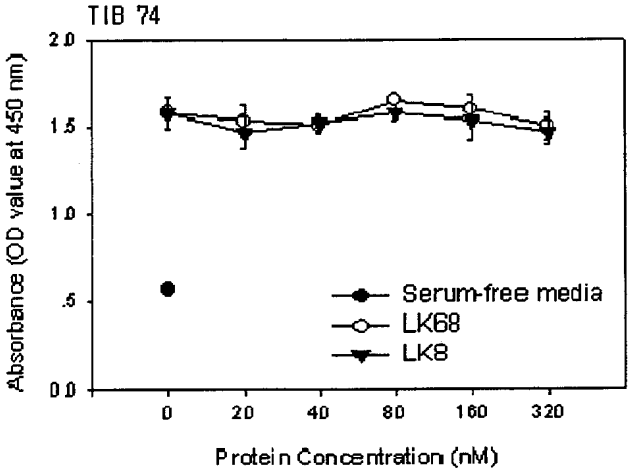


FIG. 5(C)

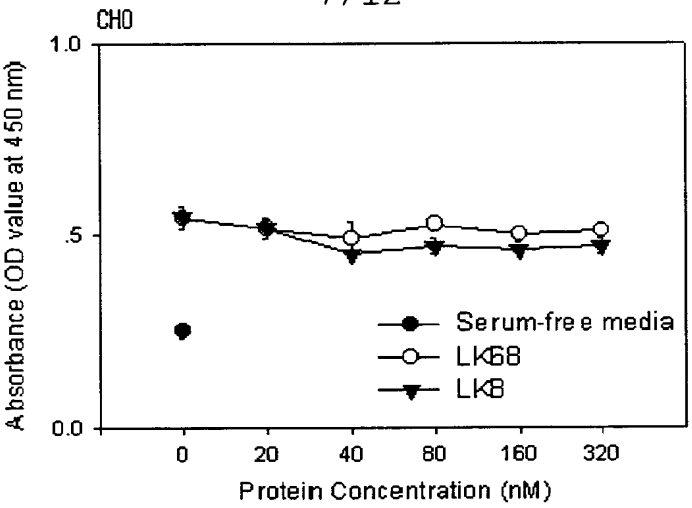


FIG. 5(D)

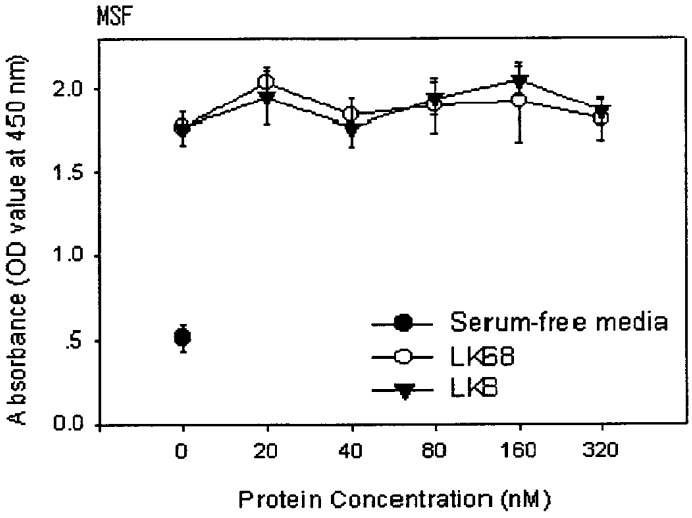


FIG. 5(E)

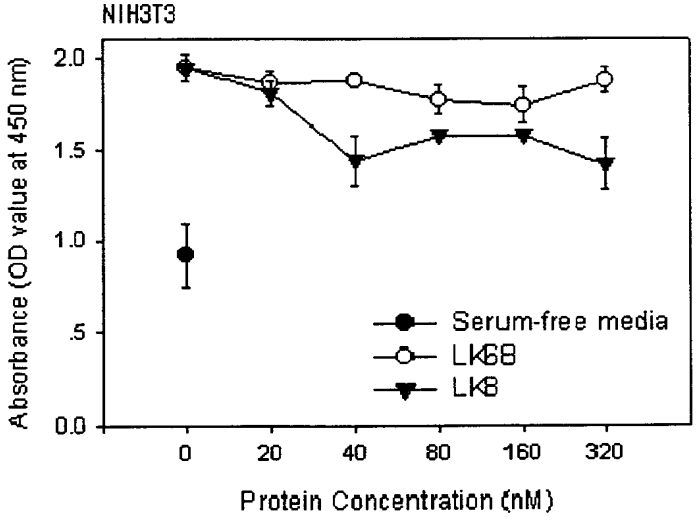


FIG. 5(F)

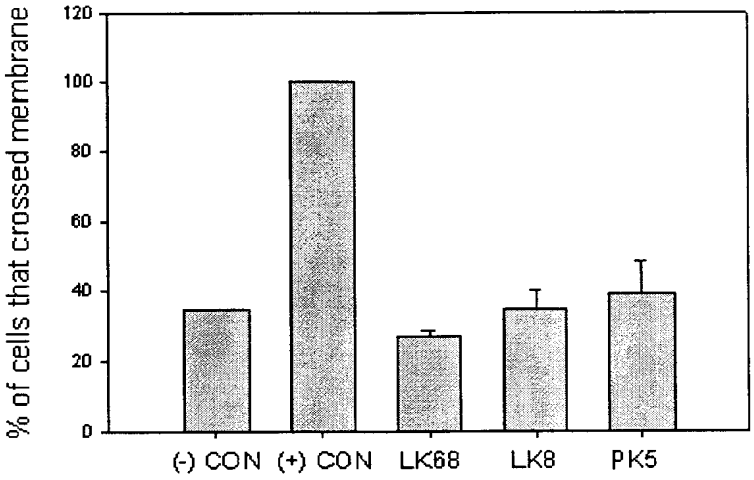

% of cells that crossed membrane
120
100
80
60
40
20
0
(-) CON
(+) CON
LK68
LK8
PK5

FIG. 6(A)

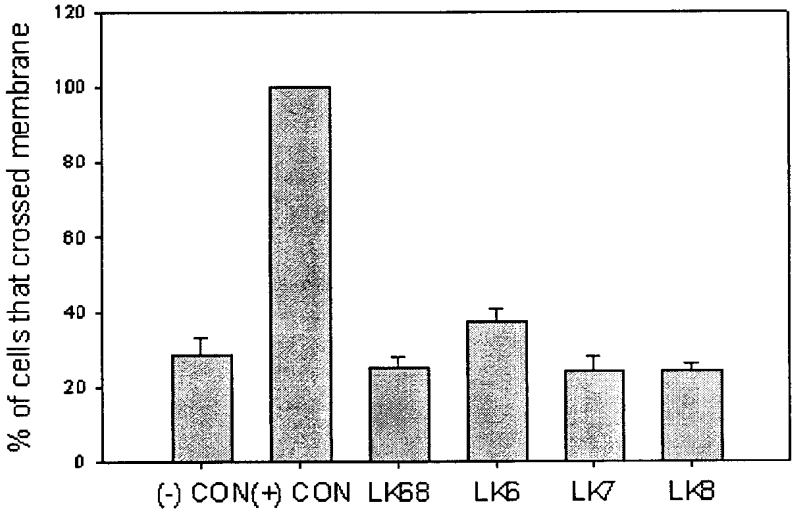

% of cells that crossed membrane
120
100
80
60
40
20
0
(-) CON
(+) CON
LK68
LK6
LK7
LK8

FIG. 6(B)

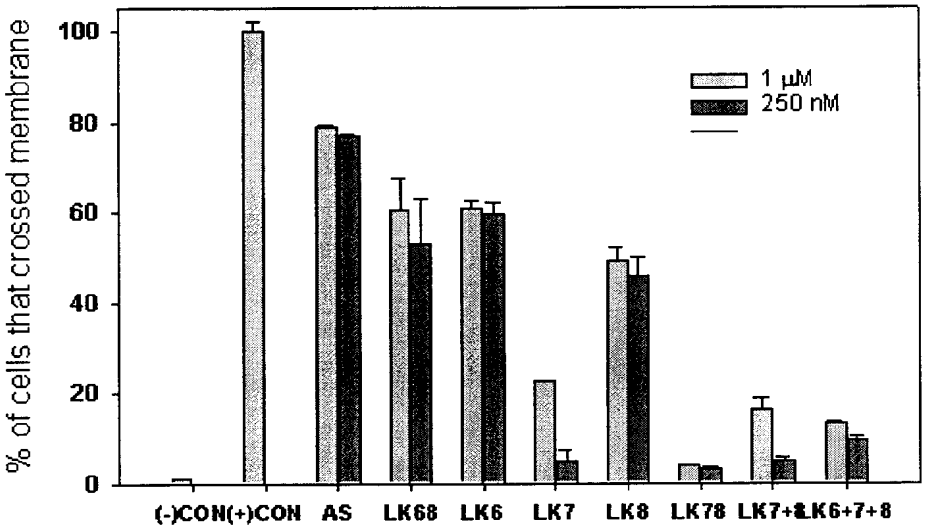

% of cells that crossed membrane
100
80
60
40
20
0
1 μM
250 nM
(-)CON
(+)CON
AS
LK68
LK6
LK7
LK8
LK78
LK7+8
LK6+7+8

FIG. 7

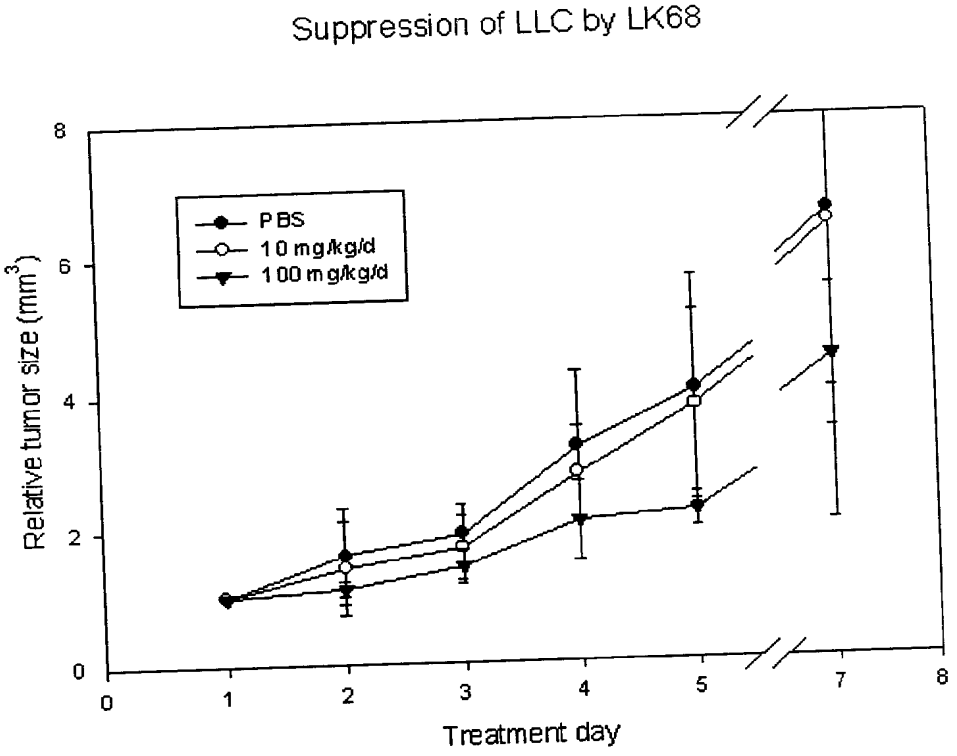

Suppression of LLC by LK68
PBS
10 mg/kg/d
100 mg/kg/d
Relative tumor size (mm3)
Treatment day
0
2
4
6
8
0
1
2
3
4
5
7
8

FIG. 8

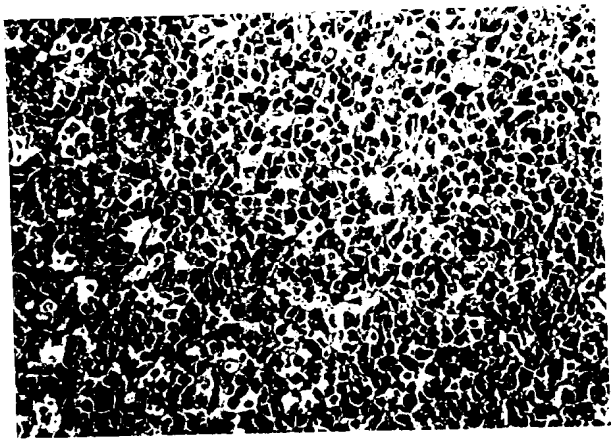


FIG. 9(A)

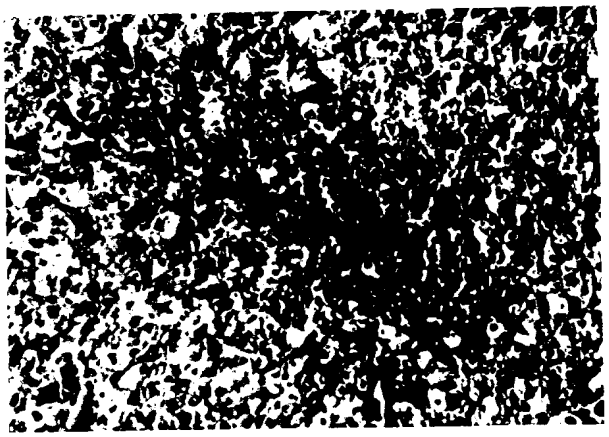


FIG. 9(B)

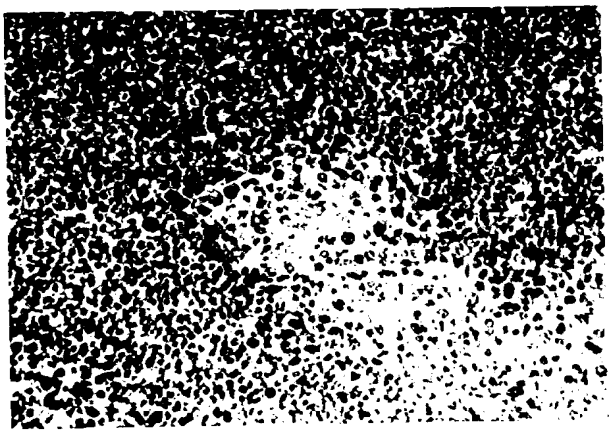
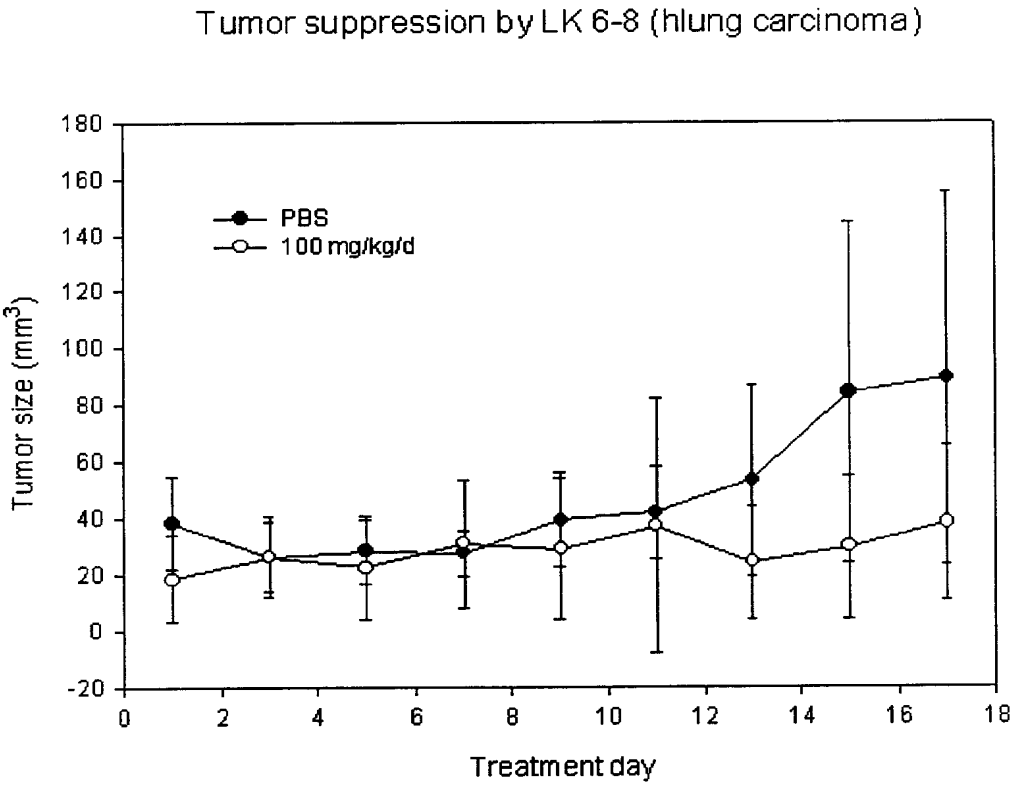


FIG. 9(C)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100 mg/kg/d
Tumor size (mm3)
Treatment day
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160
140
120
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16
18

FIG. 10

SEQUENCE LISTING

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Gln Pro Trp Cys Tyr Thr Thr Asp Pro Cys Val Arg Trp Glu Tyr Cys
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Asn Leu Thr Gln Cys Ser Glu Thr Glu Ser Gly Val Leu Glu Thr Pro
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Thr Val Val Pro Val Pro Ser Met Glu Ala His Ser Glu Ala Ala Pro
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Thr Glu Gln Thr Pro Val Val Arg Gln Cys Tyr His Gly Asn Gly Gln
115 120 125

Ser Tyr Arg Gly Thr Phe Ser Thr Thr Val Thr Gly Arg Thr Cys Gln
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Ser Trp Ser Ser Met Thr Pro His Arg His Gln Arg Thr Pro Glu Asn
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Tyr Pro Asn Asp Gly Leu Thr Met Asn Tyr Cys Arg Asn Pro Asp Ala
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Asp Thr Gly Pro Trp Cys Phe Thr Thr Asp Pro Ser Ile Arg Trp Glu
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Tyr Cys Asn Leu Thr Arg Cys Ser Asp Thr Glu Gly Thr Val Val Ala
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Pro Pro Thr Val Ile Gln Val Pro Ser Leu Gly Pro Pro Ser Glu Gln
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Asp Cys Met Phe Gly Asn Gly Lys Gly Tyr Arg Gly Lys Lys Ala Thr
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Arg His Ser Thr Phe Ile Pro Gly Thr Asn Lys Trp Ala Gly Leu Glu
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 99/00554

CLASSIFICATION OF SUBJECT MATTER

IPC[7]: C 07 K 14/47; C 12 N 15/63, 15/70, 1/21; A 61 K 38/17

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC[7]: C 07 K 14/00; C 12 N; A 61 K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CA Database, STN International, Karlsruhe (DE), Registry Database, STN International, Karlsruhe (DE), WPI Database, Derwent Publications Ltd., London (GB)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LOGRASSO et al."Cloning, Expression, and Characterization of Human Apolipoprotein (a) Kringle IV37", The Journal of Biological Chemistry, Vol.269, No.34, August 1994, pages 21820-21827, totality.	1-19
A	SCANU et al." Apolipoprotein (a): Structural and Functional Consequences of Mutations in Kringle Type 10 (or Kringle 4-37)", Clinical Genetics, Vol.46, 1994, pages 42-45, totality.	1-19
A	SCANU et al."A Single Point Mutation (Trp72=> Arg) in Human apo(a) Kringle 4-37 Associated with a Lysine Binding Defect in Lp(a)", Biochimica et Biophysica Acta, Vol 1227, 1994, pages 41-45, totality.	1-19
A	GABEL et al."Sequences within Apolipoprotein(a) Kringle IV Types 6-8 Bind Directly to Low-Density Lipoprotein and Mediate Noncovalent Association of Apolipoprotein(a) with Apolipoprotein B-100", Biochemistry, Vol.37, 1998, pages 7892-7898, totality.	1-19

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 May 2000 (05.05.2000)	2 August 2000 (02.08.2000)
Name and mailing adress of the ISA/AT Austrian Patent Office Kohlmarkt 8-10; A-1014 Vienna Facsimile No. 1/53424/535	Authorized officer Weniger Telephone No. 1/53424/

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